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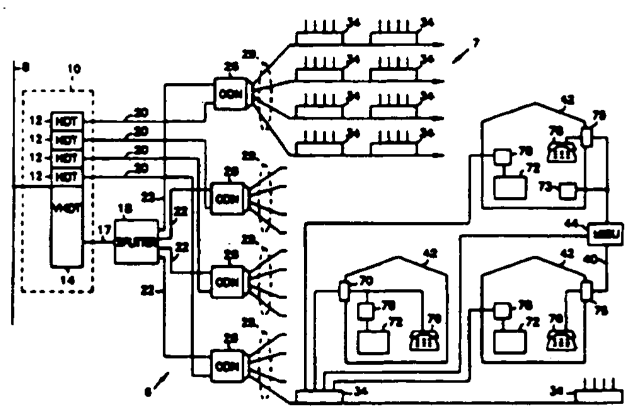

(57) Abstract

A video and telephony signal distribution network having a head end including an optical transmitter for transmitting optical downstream video and telephony signals on at least one optical fiber in a first frequency bandwidth and a receiver for receiving optical upstream data signals. The network further includes at least one optical/electrical converter unit which includes a receiver for receiving the optical downstream video and telephony signals and converts the optical downstream video and telephony signals into a plurality of downstream electrical output signals. A coaxial distribution system provides for transmission of one of the downstream electrical output signals from the optical/electrical converter unit to a service unit connected to at least one remote unit. The service unit includes a transmitter for transmitting upstream electrical data signals generated at the remote units via a coaxial distribution system to an optical/electrical converter unit connected thereto within a second frequency bandwidth. The second frequency bandwidth is reused for transmission by each service unit connected to each remote unit. The optical/electrical converter unit receives the upstream electrical data signals from a plurality of the service units and converts the upstream electrical data signals for transmittal as an optical upstream data signal to the head end.

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HYBRID FIBER/COAX VIDEO AND TELEPHONY COMMUNICATION SYSTEM

Field of the Invention

The present invention relates generally to the field of communication systems. More particularly, the present invention relates to a bidirectional communications network employing an architecture utilizing both optical fiber and coaxial cable media.

Background of the Invention

Two information services found in households and businesses today include television or video services and telephone services. Another information service involves digital data transfer which is most frequently accomplished using a modem connected to a telephone service. All further references to telephony herein shall include both telephone services and digital data transfer services.

Characteristics of telephony and video signals are different and therefore telephony and video networks are designed differently as well. For example, telephony information is relatively narrow band when compared to video signals. In addition, telephony signals are low frequency whereas NTSC standard video signals are transmitted at carrier frequencies greater than 50 MHz. Accordingly, telephone transmission networks are relatively narrow band systems which operate at audio frequencies and which typically serve the customer by twisted wire drops from a curb-side junction box. On the other hand, cable television services are broad band and incorporate various frequency carrier mixing methods to achieve signals compatible with conventional very high frequency television receivers. Cable television systems or video services are typically provided by cable television companies through a shielded cable service connection to each individual home or business.

One attempt to combine telephony and video services into a single network is described in U.S. Patent No. 4,977,593 to Balance entitled "Optical Communications Network." Balance describes a passive optical

communications network with an optical source located in a central station. The optical source transmits time division multiplexed optical signals along an optical fiber and which signals are later split by a series of splitters between several individual fibers servicing outstations. The network allows digital speech data to be transmitted from the outstations to the central station via the same optical path. In addition, Balance indicates that additional wavelengths could be utilized to add services, such as cable television, via digital multiplex to the network.

A 1988 NCTA technical paper, entitled "Fiber Backbone: A Proposal For an Evolutionary Cable TV Network Architecture," by James A. Chiddix and David M. Pangrac, describes a hybrid optical fiber/coaxial cable television (CATV) system architecture. The architecture builds upon existing coaxial CATV networks. The architecture includes the use of a direct optical fiber path from a head end to a number of feed points in an already existing CATV distribution system.

U.S. Patent No. 5,153,763 to Pidgeon, entitled "CATV Distribution Networks Using Light Wave Transmission Lines," describes a CATV network for distribution of broad band, multichannel CATV signals from a head end to a plurality of subscribers. Electrical to optical transmitters at the head end and optical to electrical receivers at a fiber node launch and receive optical signals corresponding to broad band CATV electrical signals. Distribution from the fiber node is obtained by transmitting electrical signals along coaxial cable transmission lines. The system reduces distortion of the transmitted broad band CATV signals by block conversion of all or part of the broad band of CATV signals to a frequency range which is less than an octave. Related U.S. Patent No. 5,262,883 to Pidgeon, entitled "CATV Distribution Networks Using Light Wave Transmission Lines," further describes the distortion reducing system.

Although the above-mentioned networks describe various concepts for transmitting broad band video signals over various architectures, including hybrid optical fiber/coax architectures, none of these references describes a cost effective, high quality, protectable bi-directional

telecommunications network capable of narrow band telephony communications as well as broad band video communications which employ existing telephone and cable television distribution networks. Therefore, a need for such a bi-directional telephony and video communications network, and features for enhancing such a network, currently exists.

Summary of the Invention

The present invention is a hybrid fiber/coax video and telephony communication network which integrates bi-directional telephony and interactive video services into one network including optical fiber and coaxial cable distribution systems. The present invention utilizes optical fiber as the transmission medium for feeding a plurality of optical distribution nodes with video and telephony information from a head end. Coaxial cable distribution systems are utilized for connection of the distribution nodes to a plurality of remote units. The head end optically transmits the video information downstream to the nodes where it is converted to electrical signals for distribution to the remote units. Telephony information is also optically transmitted to the nodes in frequency bandwidths unused by the video information. The downstream telephony and video optical signals are converted to electrical telephony and video signals for distribution to the plurality of remote units. The network provides for transmission of upstream electrical data signals, for example telephony signals, to the head end by transmitting from the remote units upstream electrical data signals to the distribution nodes where such upstream electrical data signals are converted to upstream optical signals for transmission to the head end.

In one embodiment, the head end includes a first distribution terminal having at least one optical transmitter for transmitting optical downstream telephony signals on at least one optical fiber. In addition, the head end includes a second distribution terminal having a separate optical transmitter for transmitting an optical downstream video signal on an optical fiber line.

In another embodiment, the video and telephony signal distribution network transmits optical downstream video and telephony signals

on at least one optical fiber in a first frequency bandwidth. In this embodiment, a second frequency bandwidth is reused for transmission of upstream electrical data signals generated at the remote units. The second frequency bandwidth is reused for transmission by each remote unit.

In another embodiment of the invention, a filter is utilized at service units which interface the coaxial distribution systems to user equipment. The ingress filter allows for passage of downstream video signals to video equipment units and blocks downstream telephony signals transmitted in a different frequency bandwidth.

Brief Description of the Drawings

Figure 1 shows a block diagram of a hybrid fiber/coax network in accordance with the present invention.

Figure 2 is a block diagram of a head end host distribution terminal of the network of Figure 1.

Figure 3 is a block diagram of an optical distribution node of the network of Figure 1.

Figure 4 is a block diagram of a home coaxial line unit of the network of Figure 1.

Figure 5 is a block diagram of an alternative embodiment for transmission from the head end to the optical distribution nodes in accordance with the present invention.

Figure 6 is a block diagram of an impulse shaping technique utilized in accordance with the present invention.

Figure 7 is a block diagram of an alternative embodiment of the optical to electrical converter of the head end host distribution terminal of Figure 2.

Figure 8 is a block diagram of an alternative embodiment of the head end host distribution terminal of Figure 2.

Detailed Description of the Preferred Embodiment

With reference to Fig. 1, a general description of a hybrid fiber/coax communications network 6 in accordance with the present invention shall be described. Telephony and video information from existing telephone

and video services generally shown by trunk line 8 is received by and processed by head end 10. Head end 10 includes a plurality of host distribution terminals (HDT) 12 for telephony data interface and video host distribution terminal (VHDT) 14 for video data interface. Host distribution terminals 12 and VHDT 14 include transmitters and receivers for communicating the video and telephony information between the video and telephony signal distribution network 6 in accordance with the present invention and the existing telephony and video services as represented generally by trunk line 8.

The video information is optically transmitted downstream via optical fiber line 17 to splitter 18 which splits the optical video signals for transmission on a plurality of optical fibers 22 to a plurality of optical distribution nodes 26. The HDT 12 transmits optical telephony signals via optical fiber link 20 to the optical distribution nodes 26. The optical distribution nodes 26 convert the optical video signals and telephony signals for transmission as electrical outputs via a coaxial distribution system 7 to a plurality of remote units 42. The electrical downstream video and telephony signals are distributed via a plurality of coaxial lines 29 and coaxial taps 34 of the coaxial distribution system 7.

The remote units 42 include means for transmitting upstream electrical data signals including telephony information from telephones 76 and data terminals 73 and in addition may include means for transmitting set top box information from set top boxes 78. The upstream electrical data signals are provided by a plurality of remote units 42 to an optical distribution node 26 connected thereto. The optical distribution node 26 converts the upstream electrical data signals to an upstream optical data signal for transmission via optical fiber link 20 to the head end 10.

The present invention shall now be described in further detail with reference to Figs. 1-8. The first part of the description shall primarily deal with downstream transmission and the second part of the description shall primarily be with regard to upstream transmission. The video and telephony distribution network 6 in accordance with the present invention,

includes head end 10 which receives video and telephony information from video and telephony service providers via trunk line 8. Head end 10 includes a plurality of host distribution terminals 12 and a video host distribution terminal 14. The HDT 12 includes a transmitters and receivers for communicating telephony information, such as T1, ISDN, or other data services information, to and from telephony service providers via trunk line 8 and the VHDT 14 includes a transmitters and receivers for communicating video information, such as cable TV video information and interactive data of subscribers to and from video service providers via trunk line 8.

The VHDT 14 transmits downstream optical signals to a splitter 18 via video feeder optical fiber line 17. The passive optical splitter 18 effectively makes four copies of the downstream high bandwidth optical video signals. The duplicated downstream optical video signals are distributed to the correspondingly connected optical distribution nodes 26. One skilled in the art will readily recognize that although four copies of the downstream video signals are created, that any number of copies may be made by an appropriate splitter and that the present invention is not limited to any specific number.

The splitter 18 is a passive means for splitting broad band optical signals without the need to employ expensive broad band optical to electrical conversion hardware. Optical signal splitters are commonly known to one skilled in the art and available from numerous fiber optic component manufacturers such as Gould, Inc. In the alternative, active splitters may also be utilized. In addition, a cascaded chain of passive or active splitters would further multiply the number of duplicated optical signals for application to an additional number of optical distribution nodes and therefore increase further the remote units serviceable by a single head end. Such alternatives are contemplated in accordance with the present invention as described by the accompanying claims.

The VHDT 14 can be located in a central office, cable TV head end, or a remote site and broadcast up to about 112 NTSC channels. The VHDT 14 includes a transmission system like that of a LiteAMp™ system

available from American Lightwave Systems, Inc., currently a subsidiary of the assignee hereof. Video signals are transmitted optically by amplitude modulation of a 1300 nanometer laser source at the same frequency at which the signals are received (i.e. the optical transmission is a terahertz optical carrier which is modulated with the RF video signals). The downstream video transmission bandwidth is about 54-725 MHz. One advantage in using the same frequency for optical transmission of the video signal as the frequency of the video signals when received is to provide high bandwidth transmission with reduced conversion expense. This same-frequency transmission approach means that the modulation downstream requires optical to electrical conversion or proportional conversion with a photodiode and perhaps amplification, but no frequency conversion. In addition, there is no sample data bandwidth reduction and little loss of resolution.

Alternative embodiments of the VHDT may employ other modulation and mixing schemes or techniques to shift the video signals in frequency, and other encoding methods to transmit the information in a coded format. Such techniques and schemes for transmitting analog video data, in addition to those transmitting digital video data., are known to one skilled in the art and are contemplated in accordance with the spirit and scope of the present invention as described in the accompanying claims.

Telephony information is transmitted downstream by HDT 12 via optical fiber link 20 to a corresponding optical distribution node 26. A more detailed block diagram of one of the HDTs 12 is shown in Fig. 2. Each HDT 12 includes an RF modem bank 50 which receives telephony information via trunk line 8. The RF modem bank 50 includes four RF modem modules 52 and a protection modem module 54. Each RF modem module receives telephony information, for example time division multiplexed channel signals from a public switched telephone service, via trunk line 8 and the telephony information modulates an analog carrier for transmission of the downstream optical telephony data by downstream optical telephony transmitter 80 of downstream telephony electrical to optical converter 64 to a corresponding distribution node 26. Each RF modem module includes a

transceiver 53 and provides a downstream electrical telephony signal in one of four frequency bandwidths, each bandwidth being about 6 MHz in width like that of a CATV channel. Each 6 MHz bandwidth channel transmits data at 22 Mbits/sec and can provide for transmission of 8T1 digital telephone signals; T1 being a conventional telephone signal where 24 voice channels are sampled at an 8 KHz rate, with 8 bits per sample (each 8 bit conversation sample is termed a DSO). Each of these signals from the four RF modem modules 52 are transmitted via coax patch cables to a combiner 82 of downstream telephony electrical to optical converter 64 for transmission by optical transmitter 80. Therefore, the spectrum for the downstream optical telephony data is four separated 6 MHz frequency bands containing 22 Mbits/sec of data within each 6 MHz bandwidth. The four 6 MHZ frequency bands, separated by a guard band as is known to one skilled in the art, are transmitted in about the 725-800 MHz bandwidth.

Any number of modulation techniques may be used for transmission of the telephony information downstream. The transmission downstream is point to multipoint transmission using broadcast type transmission schemes. The modulation techniques utilized and performed by RF modem module 52 may include quadrature phase shift keying (QPSK), quadrature amplitude modulation (QAM), or other modulation techniques for providing the desired data rate. Modulation techniques, such as QPSK and QAM, are known to those skilled in the art and the present invention contemplates the use of any such modulation techniques for downstream broadcast transmission.

The electrical to optical converter 64 includes two transmitters 80 for downstream telephony transmission to protect the telephony data transmitted. These transmitters are conventional and relatively inexpensive narrow band laser transmitters. One transmitter is in standby if the other is functioning properly. Upon detection of a fault in the operating transmitter, controller 60 switches transmission to the standby transmitter. In contrast, the transmitter of the VHDT 14 is relatively expensive as compared to the transmitters of HDT 12 as it is a broad band analog DFB laser transmitter.

Therefore, protection of the video information, non-essential services unlike telephony data, is left unprotected. By splitting the telephony data transmission from the video data transmission, protection for the telephony data alone can be achieved. If the video data information and the telephony data were transmitted over one optical fiber line by an expensive broad band analog laser, economies may dictate that protection for telephony services may not be possible. Therefore, separation of such transmission is of importance.

As an alternative embodiment for providing transmission of optical video and telephony signals to the optical distribution nodes 27 from head end 10 as shown in Fig. 5, the HDT 12 and VHDT 14 can utilize the same optical transmitter and the same optical fiber line 16. The signal then is split by splitter 18 and four split signals are provided to the optical distribution nodes 27 for distribution to the remote units 42 by the coaxial distribution system 7 as further discussed below. However, as described above, the optical transmitter utilized would be relatively expensive due to its broad band capabilities, lessening the probabilities of being able to afford protection for essential telephony services.

As one skilled in the art will recognize, optical link 20, as shown in Fig. 2, may include four fibers, two for transmission downstream from electrical to optical converter 64 and two for transmission upstream to optical to electrical converter 66. With the use of directional couplers, the number of such fibers may be cut in half. In addition, the number of protection transmitters and fibers utilized may vary as known to one skilled in the art and any listed number is not limiting to the present invention as described in the accompanying claims.

RF modem bank 50 includes a protection RF modem module 54 with a transceiver 53 connected to combiner 82 of electrical to optical converter 64. Protection RF modem module 54 is further coupled to controller 60. When a fault is detected with regard to the transmission of one of the RF modem modules 52, a signal is generated and applied to an input 62 of controller 60. Controller 60 is alerted to the fault and provides appropriate signalling to switch the protection RF modem module 54 for the

faulted RF modem such that the protection RF modem module 54 transmits within the 6 MHz bandwidth of the faulted RF modem module 52 so that the four 6 MHz bandwidth signal transmission is continued on optical fiber link 20. The use of one protection RF modem module 54 for four RF modem modules 52 is only one embodiment of the present invention and the number of protection RF modem modules relative to RF modem modules may vary as known to one skilled in the art and described in the accompanying claims. As shown in Figure 8, RF modem bank 50 may include one protection module 54 for each RF modem module 52. In this embodiment, the RF modem bank 50 includes three RF modem modules 52 and three protection modules 54 for one-to-one protection.

An optical distribution node 26 as shown in Figure 3 receives both the downstream optical telephony signal and the split downstream optical video signal. The downstream optical video signal is applied by the optical fiber 22 from splitter 18 to a downstream video receiver 120 of optical distribution node 26. The optical distribution node 26 further includes downstream telephony receiver 121 for receiving the downstream optical telephony signal on optical link 20. The optical video receiver 120 utilized is like that available in the LiteAMp™ product line available from American Lightwave Systems, Inc. The converted signal from video receiver 120, proportionally converted utilizing photodiodes, is applied to bridger amplifier 127 along with the converted telephony signal from downstream telephony receiver 121. The bridging amplifier 127 simultaneously applies four downstream electrical telephony and video signals to diplex filters 134. The diplex filters 134 allow for full duplex operation by separating the transmit and receive functions when signals of two different frequency bandwidths are utilized for upstream and downstream transmission. There is no frequency conversion performed at the optical distribution nodes with respect to the video or downstream telephony signals as the signals are passed through the optical distribution nodes to the remote units via the coaxial distribution system in the same frequency bandwidth as they are received.

After the optical distribution node 26 has received downstream optical video signals via optical link 22 and downstream optical telephony signals via optical link 20 and such signals are converted to downstream electrical video and telephony signals, the four outputs of the optical distribution nodes 26 are applied to four coaxial cables 29 of coaxial cable distribution system 7 for transmission of the downstream electrical video and telephony signals to the remote units 42; such transmission occurs in about the 725-800 MHz bandwidth for telephony signals and about the 54-725 MHz bandwidth for the downstream electrical video signals. Each optical distribution node 26 provides for the transmission over a plurality of coaxial cables 29 and any number of outputs is contemplated in accordance with the present invention as described in the accompanying claims.

As shown in Fig. 1, each coaxial cable 29 can provide a significant number of remote units with downstream electrical video and telephony signals through a plurality of coaxial taps 34. Coaxial taps are commonly known to one skilled in the art and act as passive bidirectional pick-offs of electrical signals. Each coaxial cable 29 may have a number of coaxial taps connected in series. In addition, the coaxial cable distribution system may use any number of amplifiers to extend the distance data can be sent over the coaxial portions of the network 6.

The downstream electrical video and telephony signals are provided from the coaxial taps to the remote units 42 in a number of different ways. In one embodiment, the signal from the coaxial tap 34 is provided to a home integrated service unit 70 as shown in Fig. 4. The home integrated service unit 70 of Fig. 4 includes a power tap 99 coupled to a conventional power supply and ring generator 101. The downstream electrical video and telephony signals are provided to a tap 97 for application of the signals to both diplex filter 110 and ingress filter 98. The downstream video signal is provided from ingress filter 98 to video equipment 72 via set top box 78. The downstream telephony signal is applied from diplex filter 110 to RF demodulator 104 of RF modem module 102 and the demodulated signal is applied to an applicable service interface for processing and connection to

user equipment. For example, the RF demodulated signal is processed via Plain Old Telephone Service (POTS) service interface 112 for output on twisted pairs 118 to telephone 76 by POTS connection 114. The other service interfaces such as ISDN interface or a T1 interface perform their conventional functions as are known to those skilled in the art for transmittal of such information on outputs thereof to user equipment.

Ingress filter 98 provides the remote unit 42 with protection against interference of signals applied to the video equipment 72 as opposed to those provided to other user equipment such as telephones or computer terminals. Filter 98 passes the video signals; however, it blocks those frequencies not utilized by the video equipment. By blocking those frequencies not used by the video equipment, stray signals are eliminated that may interfere with the other services provided by the network to at least the same remote unit.

The set top box 78 is an optional element in the network 6. It may include an additional modem for sending interactive data therefrom back to head end 10 at frequencies unused by the video and telephony transmissions. Upstream transmission of such data is further discussed below.

Depending on the modulation processing techniques utilized at the head end 10, the RF demodulator 104 would include circuitry capable of demodulating the modulated signal. For example, if QPSK modulation is utilized then the demodulator would include processing circuitry capable of demodulating a QPSK modulated waveform as is known to one skilled in the art.

In another embodiment of providing downstream electrical video and telephony signals from the coaxial taps 34 to remote units 42, as shown in Fig. 1, a separate coaxial line form coaxial tap 34 is utilized to provide transmission of the signals therefrom to set top box 78, and thus for providing the downstream video signals to video equipment unit 72. In such a case, a second coaxial line from coaxial tap 34 would be utilized to provide the downstream telephony signals to a multiple integrated service unit (MISU) 44 which would be much like the home integrated service unit 70 as described

with regard to Fig. 4 except lacking an ingress filter 98 and tap 97. Unlike home integrated service unit 70, the MISU 44 would be utilized to service several remote units 42 with telephony services via various service interfaces. Whether the video and telephony signals are provided to the curb with use of the MISU 44 or whether the video and telephony signals are provided directly to a home integrated service unit is strictly one of application and either can be utilized with regard to the same or different coaxial taps 34 and within the same or different coaxial distribution systems 7.

In addition, an optional network interface device (NID) 75 is utilized in the connection of telephone services to the remote units 42, whether they are homes or businesses, as is known to those skilled in the art and as shown in Fig. 1. The NID is generally shown by block 70 representing the home integrated service unit but is not shown in the detail of Fig. 4. The NID performs service functions for the telephone service provider such as looping back signals to the service provider that reach the NID so as to indicate whether a failure has occurred somewhere in transmission to the NID or in connections from the NID to the user equipment when a failure is reported to the service provider.

The above description primarily involves the downstream transmission of video and telephony information from head end 10 to remote units 42. The upstream transmission of interactive data from set top boxes 78 and other data, for example telephony from telephones 76, shall now be described with reference to Figs. 1-8. The description shall be limited to transmission from remote units via home integrated service units as transmission from an MISU is substantially similar and easily ascertainable from such description. Home integrated service unit 74 provides set top box information from set top box 78 and telephony information from the service interfaces 112, including information from telephone 76, to the optical distribution mode 26 connected thereto by the same coaxial path as for the downstream communication. The set top box signals are transmitted by a separate RF modem of the video service provider at a relatively low frequency in the bandwidth of about 5 to 40 MHz which is unused by

telephony and video services. The telephony signals are also transmitted upstream in the 5-40 MHz bandwidth, usually from 10 MHz to 30 MHz. This 5-40 MHz bandwidth is reused in each coaxial path 29 from each remote unit 42 to the respectively connected optical distribution node 26. As such, upstream electrical telephony data signals from the remote units are transmitted at the same reused frequency bandwidth of 5-40 MHz on each coaxial line 29 for input to the optical distribution node 26. Therefore, as shown in Fig. 3, four upstream electrical telephony signals, each in the 5-40 MHz bandwidth, are input to optical distribution node 26, via the respectively connected coaxial cables 29.

The upstream transmission from an integrated service unit for multipoint to point transmission utilizes time multiplexing techniques, although any of a number of multiple access techniques known to those skilled in the art are contemplated in accordance with the present invention. All the remote units are designated a time slot for transmission. In such a case each remote unit must transmit at a particular time to maintain multiple access with the timing being supplied using data on the downstream paths. The upstream data is transmitted on a bit-by-bit basis. With each remote unit assigned a time slot, the RF modem 102 of the unit knows that it will not interfere with the others because it has determined the time delay for each one of them and each RF modem 102 is signalled to transmit at a precise time. Due to the high volumes of multiplexed serial data from several outlining remote stations and limited bandwidth for transmission, short pulse durations are required for better resolution of the data transmitted to the head end 10. Although the data modulates a carrier and is transmitted in the 5 to 40 MHz bandwidth by RF modulator 108, because of the limited bandwidth in the upstream direction, a pulse shaping network at each remote unit is used to generate raised cosine pulses for the rectangular or square wave bit-by-bit stream of data transmitted along the coaxial cable in the coaxial network.

An optimal pulse shape for transmission in a band limited coaxial cable network is determined by the use of Fourier calculations with a given set of boundary conditions. Also, the Fourier calculations implement a

spectral limitation constraint for the purposes of limiting the spectral content of the optimal pulse shape. Limiting the spectral content of the pulse shape serves two functions. The first function is to limit the spectral characteristics of the optimal pulse shape in order to prevent phase dispersion at the receiving end of the transmission system. The second benefit from the spectral limitation constraint is to allow the use of relatively simple finite impulse response filters with a minimal number of taps.

In one embodiment of the pulse shaping network as shown in Fig. 6, 50 nanosecond pulses from the RF modulator 108 of RF modem 102 are transmitted to a pulse sequencer 301 for uniform digitization. The output from the pulse sequencer is then applied to a ten tapped finite impulse response filter (FIR filter) 302 with associated electronics 303 to provide the addition and subtraction necessary for the filtering process. The output is sent to a line driver circuit for output to the coaxial cable through diplex filter 110. The optimal pulse waveform is a raised cosine waveform. Using such pulse shaping techniques, overcomes the difficulty of sending extremely short pulse duration information along a band limited coaxial cable.

The upstream electrical telephony signals from a plurality of remote units, including signals from the RF modems 102 and from modems in set top boxes 78, are transmitted to the respectively connected optical distribution node 26 as shown in Fig. 3 via the individual coaxial cables 29. The upstream electrical signals are applied to a diplex filter 134 respectively connected to a coaxial cable 29. One of the diplex filters 134 passes the upstream electrical telephony signal applied thereto through to combiner 125 while the other diplex filters pass the upstream electrical telephony signals applied thereto to frequency shifters 128, 130, and 132. Frequency shifter 128 shifts the upstream electrical telephony signal into the 50-85 MHz bandwidth, frequency shifter 130 shifts another upstream electrical telephony signal into the 100-135 MHz bandwidth and frequency shifter 132 shifts the other upstream electrical telephony signal into the 150-185 MHz bandwidth. The shifted signals are combined by combiner 125 and provided to upstream telephony and set top control transmitters 123. The conventional optical

transmitters 123 transmit the upstream electrical telephony signal as an upstream optical telephony signal to head end 10 via fiber optic link 20. Once again, two transmitters are available for transmission, one in standby mode, like that in the downstream transmission path.

The upstream optical telephony signals are received by upstream telephony and set top box receiver 84 of optical to electrical converter block 66. The upstream optical telephony signals are converted, split, and all the split electrical signals in the 5-40 MHz, 50-85 MHz, 100-135 MHz, and 150-185 MHz are frequency shifted back to the 5-40 MHz bandwidth by frequency shifters 86, 88, and 90 with the exception of the signal already in the 5-40 MHz bandwidth which is passed through with the other frequency shifted signals from the frequency shifters to RF switch 94. A combined signal in the 5-40 MHz bandwidth from combiner 92 is provided to the VHDT and the signal is processed for obtaining the interactive information transmitted from set top boxes 78. The RF switch 94 is controlled by controller 60 and provides the upstream telephony signals to the transceivers 53 of the corresponding RF modems 52. The upstream telephony signals are then demodulated by RF modem modules 52 and the telephony data is provided to the service providers via trunk line 8. The RF modem modules 52 include RF demodulator corresponding to the modulation techniques utilized to transmit the information upstream so such information can be recovered.

As discussed previously, the controller 60 switches protection RF modem module 54 for a transmitting RF modem module 52 in the downstream communication when a fault is detected in that module. The controller also provides signaling for switching the RF switch 94 such that the information which would have been provided to the faulted RF modem module 52 is applied to the transceiver of the protection RF modem module 54. Therefore, the protection modem module 54 is then fully within the transmit and receive loop of the system.

As shown in Fig. 7, an alternative embodiment of the present invention includes an optical to electrical converter 66 wherein the received

optical upstream telephony signal is converted by receivers 84 and the entire upstream electrical signal in the 5-200 MHz bandwidths is applied to the transceivers 53 of the RF modem modules 52. The RF modem modules 52 are then operated under control of controller 60 which assigns the RF modem module a carrier frequency to tune to for the recovery of telephony information; the assigned frequency being a function of the frequency shifting of the upstream signal. The electrical signal is still separated and frequency shifted by frequency shifters 86, 88 and 90 except for the signal already in the 5-40 MHz bandwidth and then combined by combiner 92 for application to VHDT 14.

In this embodiment, the switching of the protection modem module 54 into the system is accomplished through the controller 60. When the controller 60 detects and indicates a faulted modem module 52, the controller 60 assigns the frequency previously assigned to the faulted RF modem module to the protection module, thus establishing the protection RF modem module 54 fully within the transmit and receive loop.

In another embodiment shown in Fig. 8 including one-to-one protection for the RF modem module, neither the RF switch used for protection switching for the configuration of Fig. 2 nor the additional control required for protection switching for the configuration of Fig. 7 is necessary. In this embodiment, the same electrical signal provided to the RF modem modules 52 is applied to the corresponding protection module 54, thus only a control signal indicating which module is to be used for transmission or reception is required for the one-to-one protection.

It is to be understood, however, that even though numerous characteristics of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative and changes in matters of shape, size, number, and arrangement of the elements may be made within the principles of the invention and to the full extent indicated by the broad general meaning of the terms in which the appending claims are expressed.

What Is Claimed Is:

1. A video and telephony signal distribution network, the network comprising:

a head end for transmitting video and telephony information to a plurality of remote units, said remote units having means for receiving said video and telephony information, said head end including:

a first distribution terminal including means for transmitting an optical downstream telephony signal on at least one optical fiber and means for receiving an optical upstream data signal, and

a second distribution terminal including means, separate from said first distribution terminal transmitting means, for transmitting an optical downstream video signal on an optical fiber line;

at least one optical/electrical converter unit, said optical/electrical converter unit including means for receiving said optical downstream video signal and means for receiving said optical downstream telephony signal, each of said optical/electrical converter units for converting said optical downstream video signal and said optical downstream telephony signal into at least one downstream electrical output signal; and

at least one coaxial distribution system, said coaxial distribution system for transmission said at least one downstream electrical output signal from said at least one optical/electrical converter unit to at least one of said plurality of remote units, each remote unit having means for transmitting upstream electrical data signals generated at said remote units via said at least one coaxial distribution system to an optical/electrical convertor unit connected thereto, said at least one optical/electrical converter unit including means for converting said upstream electrical data signals to an optical upstream data signal for transmittal of said optical upstream data signal to said head end.

2. The network according to claim 1, wherein said first distribution terminal transmitting means includes at least two optical

transmitters for transmitting said optical downstream telephony signals on an optical fiber for each optical transmitter, only one optical transmitter transmitting during any one period of time, and wherein said second distribution terminal transmitting means includes a single optical transmitter for transmitting said optical downstream video signal on said optical fiber line.

3. The network according to claim 1, wherein said optical downstream video signal includes analog information, said information applied to said second distribution terminal at a frequency which is the same as the frequency at which it is transmitted.

4. The network according to claim 1,

wherein said first distribution terminal transmitting means includes means for transmitting said optical downstream telephony signal in a first frequency bandwidth to said optical/electrical converter unit;

wherein said second distribution terminal transmitting means optically pipelines said video information to said optical/electrical converter unit in a second frequency bandwidth;

wherein said means for transmitting upstream electrical data signals transmit said upstream electrical data signals over said coaxial distribution system to said optical/electrical converter unit connected thereto in a third frequency bandwidth reused by each remote unit, said upstream electrical data signals transmitted over at least two coaxial distribution cables of said coaxial distribution system from separate remote units; and

wherein said optical/electrical converter unit includes means for frequency shifting said upstream electrical data signals transmitted in the third frequency bandwidth reused by the remote units and means for combining the frequency shifted upstream electrical data signals for transmittal to said head end as said optical upstream data signal in a fourth frequency bandwidth which includes at least said third frequency bandwidth.

5. The network according to claim 1, wherein said at least one optical/electrical converter unit includes means for frequency shifting said upstream electrical data signals transmitted at a reused frequency bandwidth by a plurality of remote units and received by said optical/electrical converter unit and means for combining the frequency shifted upstream electrical data signals for transmittal to said head end as said optical upstream data signal in a predetermined frequency bandwidth which includes said reused frequency bandwidth.

6. The network according to claim 5, wherein said head end further includes means for converting said optical upstream data signal, means for splitting and frequency downshifting said converted upstream data signal into downshifted upstream electrical data signals in said reused frequency bandwidth.

7. The network according to claim 6, wherein said first distribution terminal includes a plurality of modem modules for transmitting and receiving said telephony information, each modem module for providing said telephony information to said first distribution terminal transmitting means for transmittal to said optical/electrical converter unit in a separate frequency bandwidth; and switch means for providing the frequency downshifted upstream electrical data signals from said splitting and frequency downshifting means to a corresponding modem module of said plurality of modem modules.

8. The network according to claim 6, wherein said first distribution terminal includes a plurality of modem modules for receiving and transmitting said telephony information, each modem module for providing said telephony information to said first distribution terminal transmitting means for transmittal to said optical/electrical converter unit in a separate frequency bandwidth, said head end including controller means for assigning each modem module a receiving frequency corresponding to the separate

frequency bandwidth which said modem module uses for providing said telephony information to said distribution terminal transmitting means.

9. The network according to claim 1, wherein the first distribution terminal means includes:

at least one modem modules for transmitting and receiving said telephony information, each of said at least one modem module providing for transmission in a separate frequency bandwidth;

at least one protection module;

controller means for controlling substitution of said at least one protection modem module for one of said at least one modem module when a fault in one of said at least one modem module is detected.

10. A video and telephony signal distribution network, the network comprising:

a head end including means for transmitting optical downstream video and telephony signals on at least one optical fiber in a first frequency bandwidth and means for receiving an optical upstream data signal;

at least one optical/electrical converter unit, said optical/electrical converter unit including means for receiving said optical downstream video and telephony signals and means for converting said optical downstream video and telephony signals into a plurality of downstream electrical output signals;

a coaxial distribution system having a plurality of coaxial cable portions, each coaxial cable portion for transmission of one of said downstream electrical output signals from said at least one optical/electrical converter unit to at least one service unit connected to at least one remote unit, said service unit including means for transmitting upstream electrical data signals generated at said remote units via said coaxial cable portion of said coaxial distribution system to an optical/electrical converter unit connected thereto in a second frequency bandwidth, said second frequency bandwidth reused for transmission by each service unit, said at least one optical/electrical converter unit including means for receiving said upstream

electrical data signals from a plurality of service units and means for converting said upstream electrical data signals for transmittal as said optical upstream data signal to said head end.

11. The network according to claim 10, wherein said means for converting said upstream electrical data signals for transmittal as said optical upstream data signal includes:

means for frequency shifting said upstream electrical data signals transmitted in said reused second frequency bandwidth by a plurality of service units; and

means for combining the frequency shifted upstream electrical data signals for transmittal to said head end as said optical upstream data signal in a predetermined frequency bandwidth which includes said reused second frequency bandwidth.

12. The network according to claim 11, wherein said head end includes:

means for converting said optical upstream data signal;

means for splitting said converted upstream data signal;

means for frequency downshifting said split upstream data signal into downshifted upstream data signals in said reused second frequency bandwidths;

a plurality of modem modules for transmitting said telephony information, each modem module providing for downstream transmission of said telephony information in a separate frequency bandwidth within said first frequency bandwidth; and

switch means for providing the frequency downshifted upstream data signals from said downshifting means to a corresponding modem module of said plurality of modem modules.

13. The network according to claim 11, wherein said head end includes a plurality of modem modules for receiving and transmitting said

telephony information, each modem module providing for downstream transmission of said telephony information in a separate frequency bandwidth within said first frequency bandwidth, said head end including controller means for assigning each modem module a receiving frequency as a function of the separate frequency bandwidth in which said modem module provides for downstream transmission of said telephony information.

14. The network according to claim 10, wherein said head end includes:

at least one modem module for transmitting and receiving said telephony information, each of said at least one modem module providing for transmission of said telephony information in a separate frequency bandwidth;

at least one protection module; and

controller means for controlling substitution of said at least one protection modem module for one of said at least one modem module when a fault in one of said at least one modem module is detected.

15. A network according to claim 10, wherein said service unit is a multiple user service unit for providing telephony information to a certain plurality of said remote units.

16. A network according to claim 15, wherein said video information is transmitted via a separate coaxial line to any of said certain plurality of said remote units.

17. A video and telephony signal distribution network, the network comprising:

a head end including means for transmitting an optical downstream video signal in a first frequency bandwidth and an optical downstream telephony signal in a second frequency bandwidth on at least one optical fiber, said head end further including means for receiving optical upstream data signals;

at least one optical/electrical converter unit, said optical/electrical converter unit including means for receiving said optical downstream video and telephony signals and means for converting said optical downstream video and telephony signals into a plurality of downstream electrical output signals;

a plurality of coaxial distribution systems, each coaxial distribution system for transmission of one downstream electrical output signal from said at least one optical/electrical converter unit to a service unit connected to at least one remote unit, said service unit including means for transmitting upstream electrical data signals generated at said remote units via one of said plurality of said coaxial distribution systems to an optical/electrical converter unit connected thereto, said at least one optical/electrical converter unit including means for receiving said upstream electrical data signals from a plurality of service units and means for converting said upstream electrical data signals to an optical upstream data signal for transmission to said head end;

wherein each of said service units include a filter for passing downstream video signals of said downstream electrical output signal in said second frequency bandwidth and blocking downstream telephony signals of said downstream electrical output signal in said first frequency bandwidth.

18. The network according to claim 17, wherein said remote unit includes at least one video equipment unit for receiving said downstream video signals from said filter.

19. The network according to claim 18, wherein said remote unit includes a set top box connected to said video equipment unit, said set top box including a modem for transmission of set top box data upstream to said optical/electrical converter unit in a frequency bandwidth unused for transmission of said upstream electrical data signals and said downstream video and telephony signals.

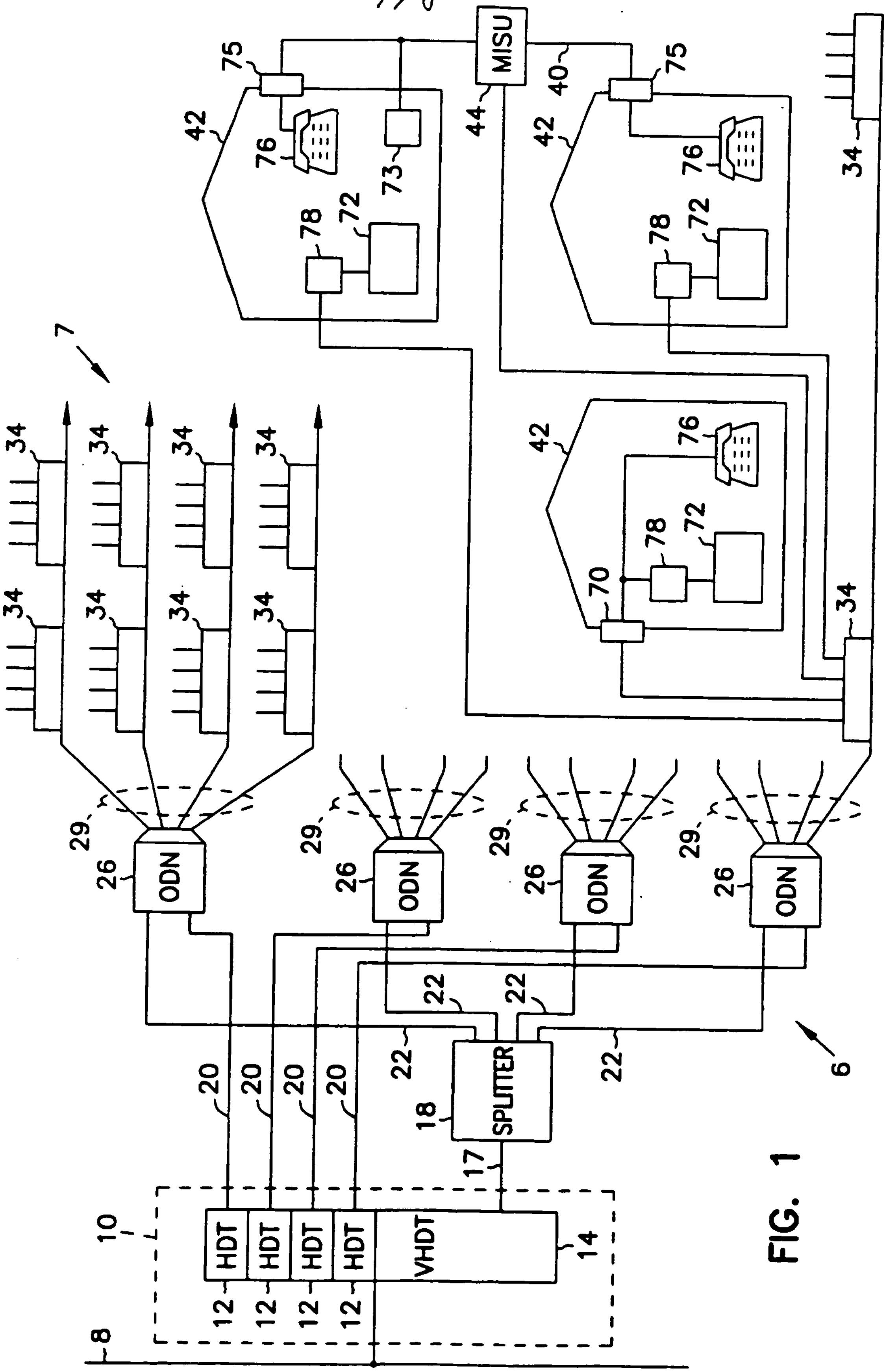
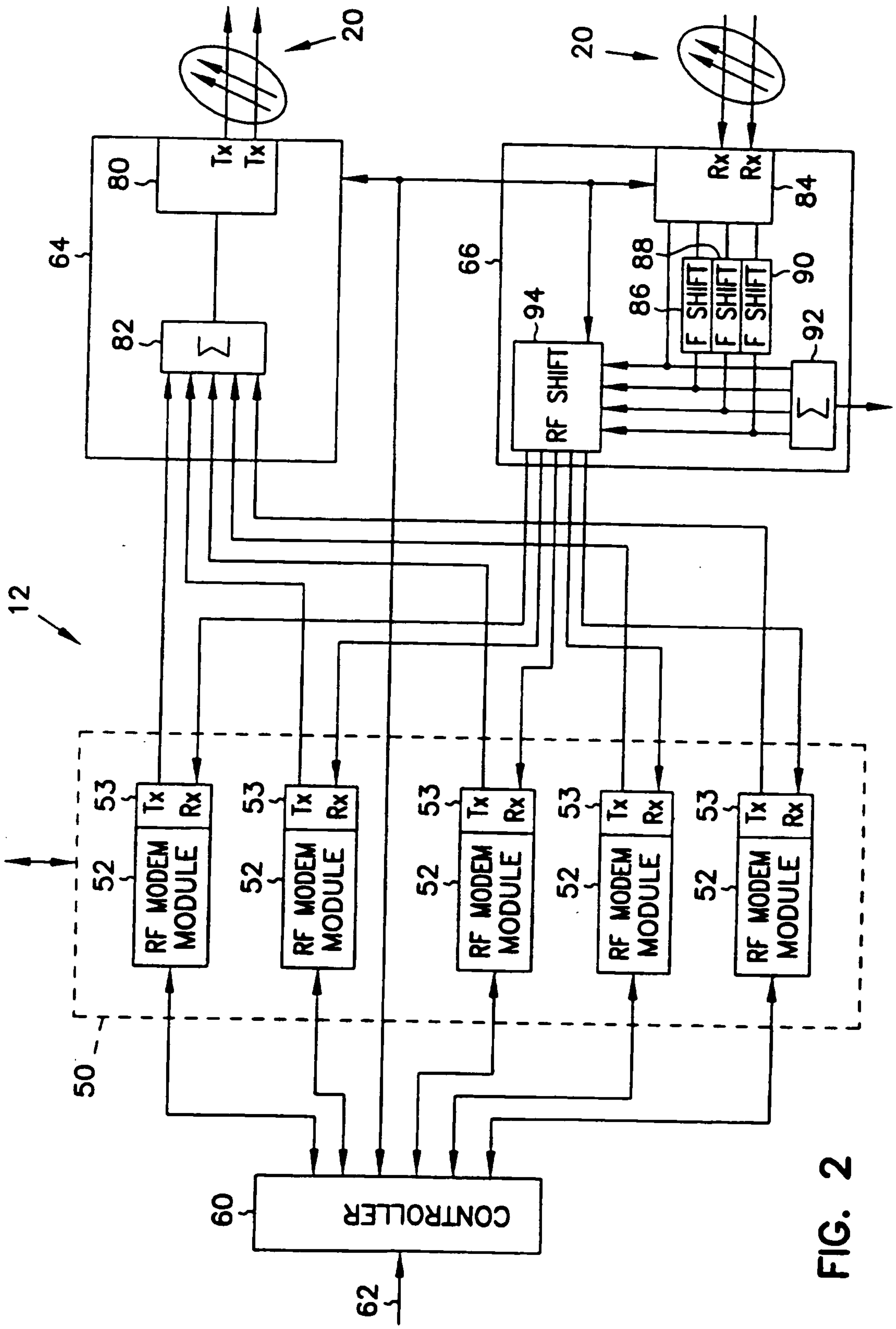


FIG. 1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20
Tx
Tx
Rx
Rx
80
84
64
66
88
86
90
F SHIFT
F SHIFT
F SHIFT
94
82
92
RF SHIFT
12
53
Tx
Rx
52
RF MODEM MODULE
50
60
CONTROLLER
62

FIG. 2

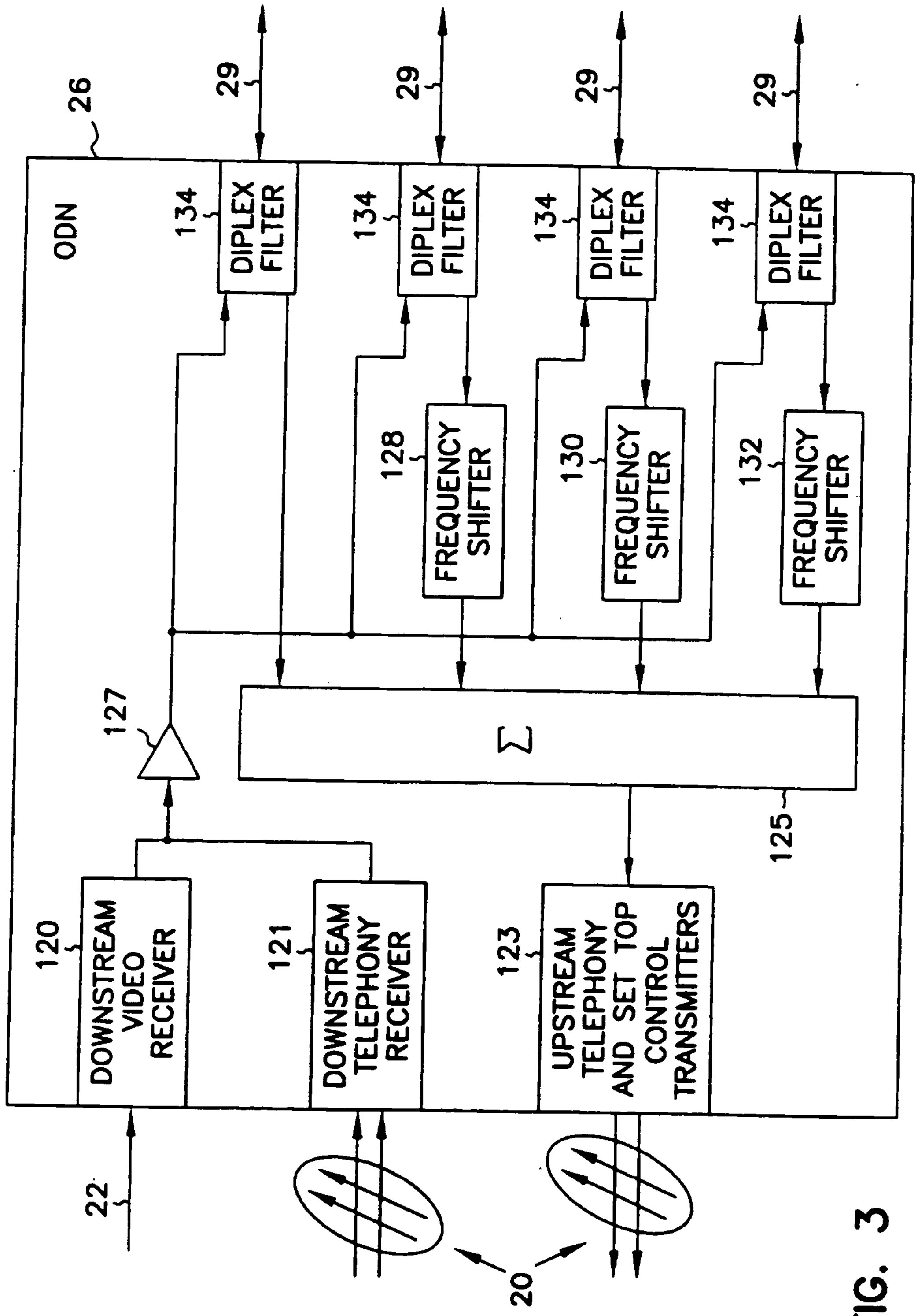
26
ODN
29
29
29
29
134
DIPLEX FILTER
134
DIPLEX FILTER
134
DIPLEX FILTER
134
DIPLEX FILTER
128
FREQUENCY SHIFTER
130
FREQUENCY SHIFTER
132
FREQUENCY SHIFTER
127
Σ
125
120
DOWNSTREAM VIDEO RECEIVER
121
DOWNSTREAM TELEPHONY RECEIVER
123
UPSTREAM TELEPHONY AND SET TOP CONTROL TRANSMITTERS
22
20

FIG. 3

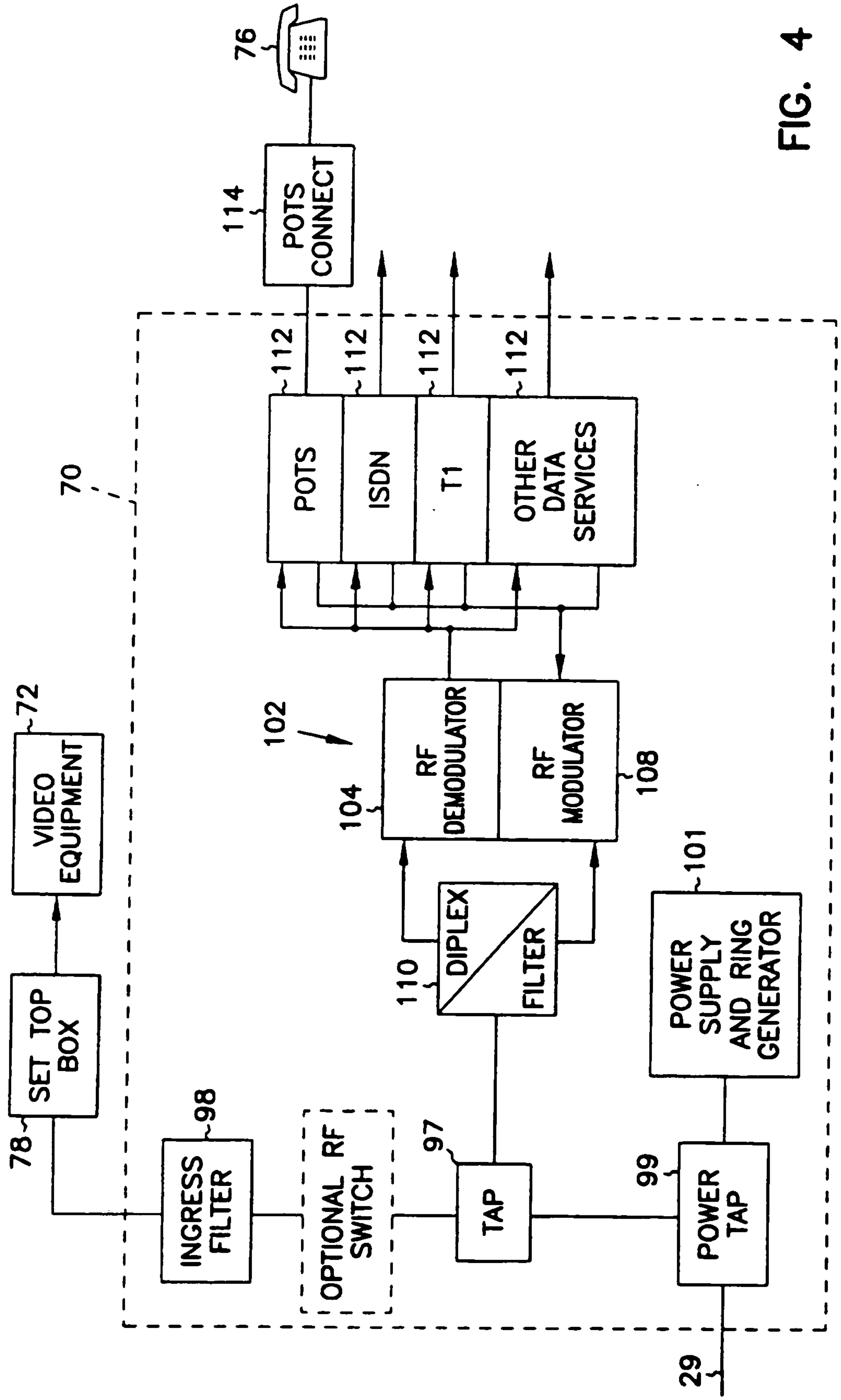
76
114
POTS CONNECT
112
70
POTS
ISDN
T1
OTHER DATA SERVICES
72
VIDEO EQUIPMENT
102
104
RF DEMODULATOR
RF MODULATOR
108
101
110
DIPLEX FILTER
POWER SUPPLY AND RING GENERATOR
78
SET TOP BOX
98
INGRESS FILTER
OPTIONAL RF SWITCH
97
TAP
99
POWER TAP
29

FIG. 4

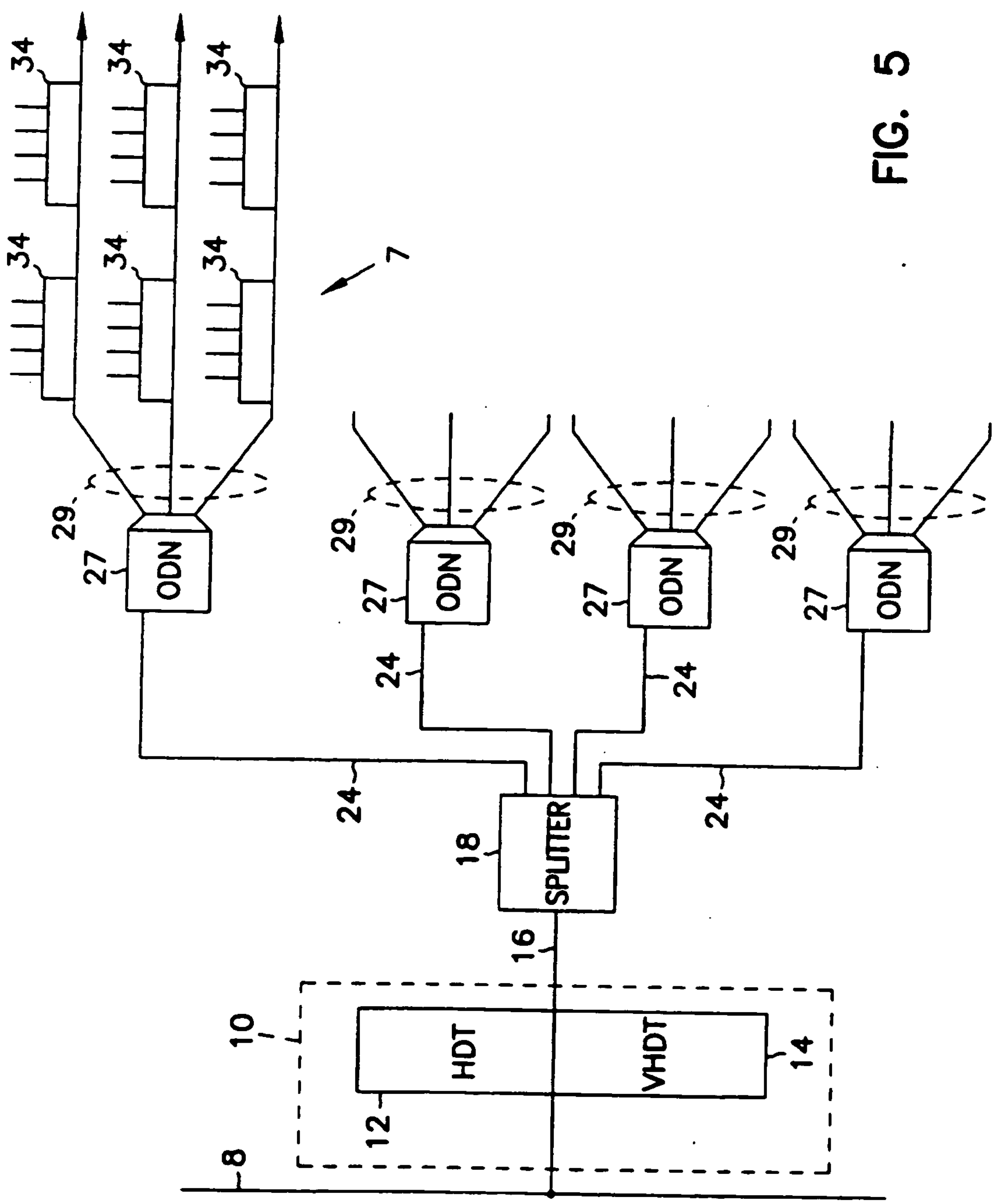

FIG. 5

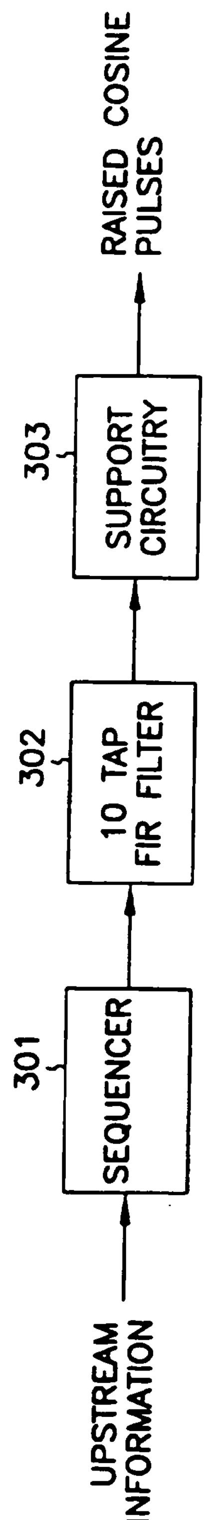
UPSTREAM INFORMATION
301
SEQUENCER
302
10 TAP FIR FILTER
303
SUPPORT CIRCUITRY
RAISED COSINE PULSES

FIG. 6

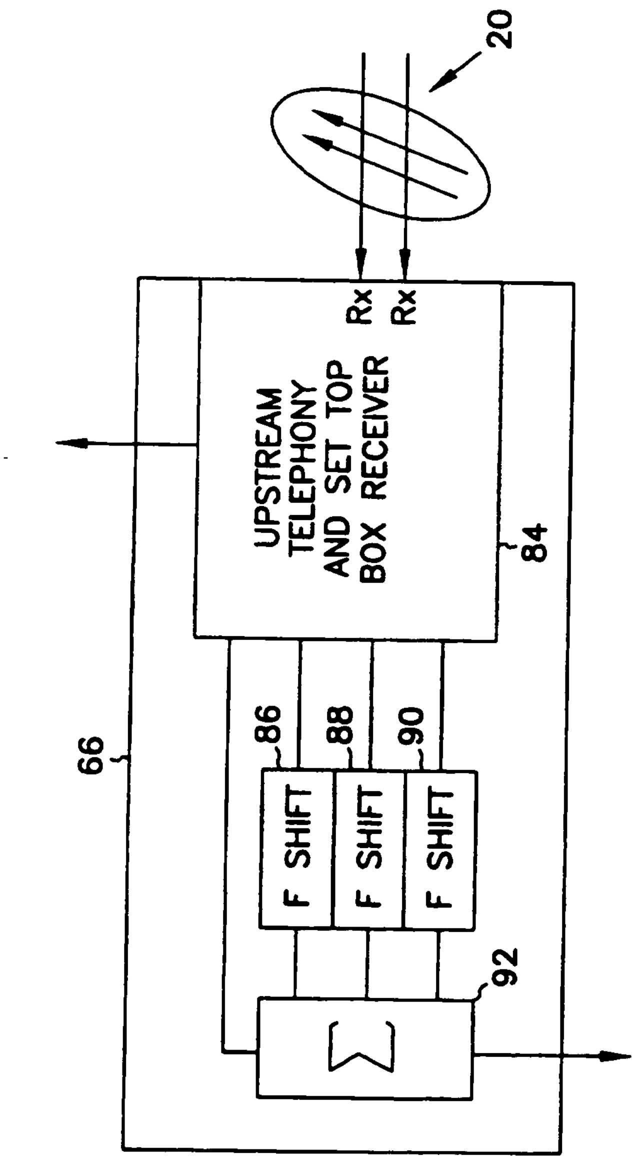
20
Rx
Rx
UPSTREAM TELEPHONY AND SET TOP BOX RECEIVER
84
66
86
88
90
F SHIFT
F SHIFT
F SHIFT
92

FIG. 7

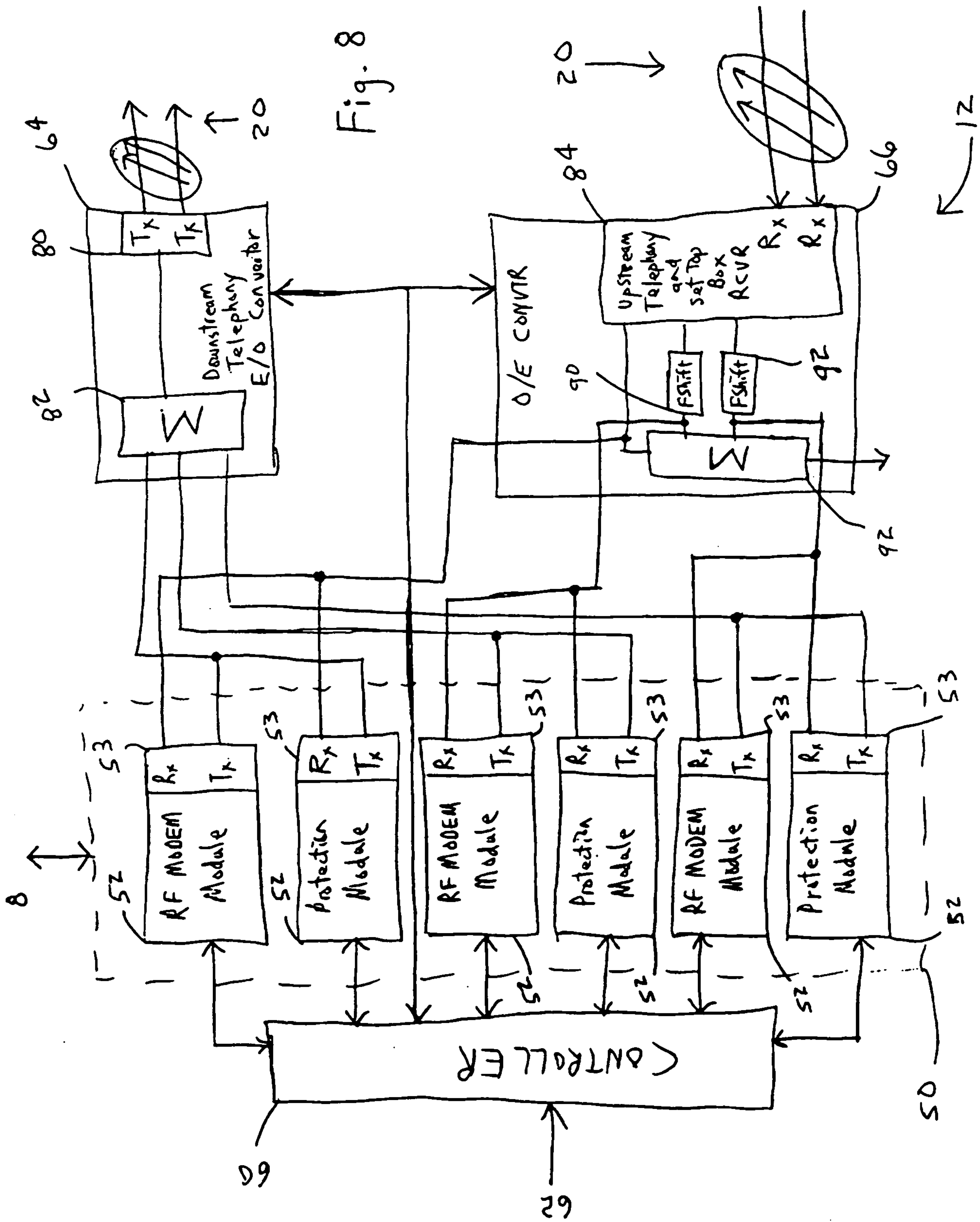
Downstream Telephony E/O Convertor
Tx
Tx
O/E CONVTR
Upstream Telephony and Set Top Box RCVR
Rx
Rx
FShift
FShift
RF MODEM Module
Protection Module
RF MODEM Module
Protection Module
RF MODEM Module
Protection Module
Rx
Tx
CONTROLLER
64
80
82
20
84
66
12
90
92
8
52
53
50
60
62

Fig. 8

Inter   nal Application No
PCT/US 95/11840

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B10/207

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 421 602 (STC) 10 April 1991 see column 2, line 10 - line 21 see column 2, line 33 - line 39 see column 2, line 50 - line 52 see column 3, line 17 - line 41 see figures 1-3	1,3,10, 17,18
Y		2,9,14, 19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 January 1996	05.02.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Williams, M.I.

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	42ND ANNUAL CONVENTION AND EXPOSITION OF THE NATIONAL CABLE TELEVISION ASSOCIATION, PROCEEDINGS, 6 - 9 June 1993 SAN FRANCISCO, US, pages 358-364, MESIYA 'A passive optical/coax hybrid network architecture for delivery of CATV, telephony and data services' see page 360, left column, line 15 - line 27 see page 360, right column, line 10 - column 26 see page 362, left column, line 6 - page 363, left column, line 26 see figures 2,3	1,3,10, 15,16
Y	---	19
Y	EP,A,0 507 379 (ALCATEL/BELL) 7 October 1992 see abstract -----	2,9,14

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 95/11840

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		DE-D- 69017135	30-03-95
		DE-T- 69017135	14-06-95
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		AU-B- 644049	02-12-93
		AU-B- 1299992	08-10-92
		JP-A- 5122151	18-05-93
		NZ-A- 241992	26-10-94
		US-A- 5299293	29-03-94